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Sediment Cores from the Cariaco Trench, Venezuela

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Sediment Cores from the Cariaco Trench, Venezuela

by

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TECHNICAL REPORT

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ABSTRACT

The Cariaco Trench, located within the limits of the continental shelf off the Caribbean coast of Venezuela, is about 160 kilometers long, 40 kilometers wide, and lies 16 to 32 kilometers offshore. Sill depth is about 150 meters; maximum depth in the trench is about 1400 meters. Within the trench, waters deeper than 375 meters are anoxic.

During cruises in 1957 and 1958, R/V ATLANTIS collected over twenty sediment cores, mostly piston type of 3 to 10 meters length, from the trench and its vicinity. The Holocene sediments from the euxinic zone of the trench are mostly grayish-olive and fine-grained; either laminated silt-clays or homogeneous silty clays, both types generally containing a paucity of benthic fauna. A lower zone of sediments, at least on the south slopes, consists of yellowish-brown silty clays containing a fair representation of benthic fauna. These appear to have been deposited under normal marine conditions before the basin waters became anoxic and are considered to be late Pleistocene in age. Greatest accumulations of sediments and highest organic contents are believed to occur in the eastern and northeastern parts of the trench.

INTRODUCTION

Hydrographic observations made in the Cariaco Trench in 1954 and 1955 revealed that its waters, cut off from the southeastern Caribbean circulation by a sill 150 meters deep, were oxygen deficient below this depth relative to the water outside the sill, and were anoxic below 375 meters (Richards and Vaccaro, 1956). The hydrographic similarity to other euxinic basins such as some of the Norwegian fjords and the Black Sea indicated that the bottom sediments might also be similar. That is, they might be primarily "black muds" of relatively high organic content, possibly future source beds of petroleum. Consequently a detailed study of cores from this basin might be of considerable interest to the petroleum geologist as well as to the stratigrapher interested in working out the recent depositional history of the area.

In late 1957, R/V ATLANTIS of the Woods Hole Oceanographic Institution made a cruise (A-240) to the Cariaco Trench area for the primary purpose of obtaining long cores of the bottom sediments. Twenty-three coring stations were occupied during this cruise, and on a subsequent cruise in 1958 (A-246) one more long core was obtained (Fig. 1). During these two cruises additional hydrographic information was obtained (Richards, 1960) and light scattering and primary production measurements were made in the trench waters (Curl, 1960).

A Kullenberg-type piston corer of three inches (7.5 centimeters) inside diameter, similar to that described by Ericson and Wollin (1956), was the main corer used. Cores ranging generally between three and ten meters in length were obtained with this device. On cruise A-240 the cores were extruded from the steel core barrels, wrapped and sealed in plastic film in approximately one meter lengths, and stored for transport to the laboratory. For cruise A-246, plastic liners had been adapted to the corer, simplifying the operation of preserving the cores for laboratory study. A small gravity corer, which served as the pilot weight for the piston corer, collected a

short core from the upper sediment layers. This is important because the upper half meter or so of a piston core is likely to be disturbed by the piston.

The first six coring attempts were made with a Hvorslev-Stetson type, two-inch (five centimeter) diameter gravity corer, fitted out with plastic core liners as were the smaller pilot corers. At the remaining eighteen core stations the piston corer was used. Statistics relating to core locations, lengths, types, water depths and general comments are given in Table I.

In the laboratory the cores were split, logged as to color and general characteristics, sampled at significant points and resealed. As far as could be determined, the wrapping on board ship was completely adequate for general stratigraphic purposes. There was apparently no loss of moisture and consequently no shrinkage. The <u>Rock Color Chart</u> published by the Geological Society of America, with a few additional color chips, was used for logging the moist color of the core sediments. The upper ten centimeters from twelve of the piston cores were forwarded to Jersey Production Research Company for various chemical analyses, the results of which are summarized in Table II. As no provision had been made for preserving these samples immediately after collection, either by freezing or with alcohol, there is some doubt as to the reliability of the results and they will not be discussed in this paper. Clay analyses were also run on these samples by the same laboratory. The results are shown in Table III and are discussed later in this paper.

Grain size analyses were run on the samples from the split sections and the silt and clay fractions were then discarded. In the ensuing discussion of the sediments of the Cariaco Trench it should be remembered that all references to faunal and mineral content, except in regard to the clay analyses just mentioned, deal only with sand sizes (diameters greater than 0.062 millimeters) and larger. These coarse fractions were examined under the low-power binocular microscope. Only a general identification of the microfauna has been attempted; sufficient to delineate the environment.

Many prepared samples are available for further study, together with the bulk of the original cores.

GEOGRAPHICAL SETTING

The Cariaco Trench, situated off the northern coast of Venezuela, between Cape Codera to the west and the Araya Peninsula to the east, is somewhat unique among submarine trenches in that it is located within the limits of the continental shelf. It is 180 kilometers long and averages about 40 kilometers wide. There is a shelf 16 to 32 kilometers wide between the coast and the southern margin of the trench along most of its length, but its eastern and western extremities lie less than 8 kilometers off shore. An elongated shoal area averaging 16 kilometers wide and generally less than 100 meters deep bounds the trench to the north and joins the mainland shelf both to the west and the east. The island of Tortuga caps this shoal north of the middle of the trench. Two passages about 150 meters deep interrupt the shoal, one at the western end north of Cape Codera, and the other to the east of Tortuga. These form the deepest connections between the Cariaco Trench and the Caribbean Sea. Between the islands of Margarita and Cubagua, and the Araya Peninsula water depths do not exceed forty meters.

The trench is divided into an eastern and a western deep basin by a saddle southeast of Tortuga at a depth of 950 meters (Fig. 2). Maximum depth in each of these basins, which are fairly flat-bottomed, is about 1400 meters. The eastern basin is narrower than the western and lies close to the southern margin of the trench, in line with the Gulf of Cariaco. To the north, between Tortuga and Margarita is a triangular platform sloping upward to 200 meters toward the north, from the slope break at about 400 meters. Two smaller basins indent this surface to depths of 400 and 500 meters below sea level. At the western end of the trench there is a similar but smaller platform sloping upward

toward the northwest at the seaward side of the trench. South of Tortuga the north slope is quite steep right up to the fifty meter contour. Steep slopes prevail along the entire south margin up to the 100 meter contour, the slope angle averaging eight degrees.

Alignment of the eastern basin with the El Pilar fault along the south shore of the Gulf of Cariaco (Rod, 1956) and of the western basin with the straight northern face of the Coast Range north of Caracas suggests that the formation of the Cariaco Trench is directly connected with post-Cretaceous, east-west fauling recently discussed by Mencher (1963). However, as that author implies, field evidence in the area is still too limited to draw any final conclusions.

SEDIMENTS

Peripheral Sediments

The first few cores of Cruise A-240 were taken in the vicinity of the western end of the Cariaco Trench. Cores 5 and 6 came from the seaward slope of the shoal area which bounds the trench on the north. Water depths at these stations were 265 and 357 meters respectively. The sediment throughout these short cores (18 and 94 centimeters) was an olive-gray, homogeneous clayey silt. Coarse fractions of the analyzed samples amounted to 12 to 17 percent by weight of the total and were composed of the tests of Quaternary foraminifera, both pelagic and benthic, in abundance, pteropods, ostracods, echinoid spines and other normal marine benthic fauna of the upper slope.

Core 1, from just north of Cape Codera at 71 meters, is the only sample taken from the upper slope of the trench shallower than sill depth. This sample consisted of 66 centimeters of calcareous fragments, terrigenous minerals, crustacean parts, mollusks, benthic foraminifera and a few pelagic foraminifera.

These deposits indicate a healthy, active, benthic environment (Pl. I-A) with a substantial contribution from an eroding coast.

Two other very short cores were obtained from within the bounds of the trench proper, but from only slightly below sill depth very near the westerly passage. Core 3, from 176 meters, consisted of only 2 centimeters of partially consolidated mollusk fragments, worm tubes and other detritus in a calcareous matrix. The corer apparently struck an outcrop here on a moderate slope at the south side of the passage. Ten centimeters of fine olive-gray silty sand were obtained in Core 4 from a gentle slope, at 180 meters depth, just north of the passage. Quaternary pelagic foraminifera were abundant, together with lesser numbers of pteropods and pelecypod larvae. Quaternary benthic foraminifera and other bottom fauna were also abundant and there was a sizable quantity (one-fourth to one-third of the coarse fraction) of worn, terrigenous detritus including reworked fossils and minerals. The shortness of this core and the fact that it took three attempts to get it, indicates a hard bottom on which there is little sedimentation at present. The Quaternary fauna present may be primarily deposits in transit, especially since the locality is quite close to one of the only two deeper channels connecting the trench and the adjacent Caribbean basin, and at times there may be fairly strong currents flowing through here.

Surface Sediments in the Trench

Two coring profiles were run across the western basin (Fig. 2: A-A' and B-B') and one across the eastern basin (Fig. 2: C-C'). Figure 3 compares the shapes of these three profiles at a vertical exaggeration of approximately twenty-five times. They are arranged on the same parallels of latitude, and show the positions of the cores. Three other cores, 15, 16, and 17 were taken within the area between Profiles B-B' and C-C' (see Fig. 1 for locations).

Core 15 was taken on the north slope of the trench just southeast of Tortuga, but was badly stirred up in coring and was not considered reliable for study. Core 16 is from the saddle area between the two main basins, and Core 17 is from the westerly end of the more or less flat bottomed area of the eastern basin.

The sediments of the bottom surface are all fine-grained silts or silty clays. They are characteristically grayish-olive and smell strongly of hydrogen sulfide. The only exception in regard to color was the occurrence of olive-brown sediment at the top of Core 20 on Profile C-C', just north of Puerto La Cruz. Here the slope is steep and it appears that the exposed sediment is not Holocene, and that any younger deposits which were originally here have slumped farther down slope.

There appears to be no consistent pattern regarding the structure, whether homogeneous or laminated, within the top few centimeters of the cores from the trench. On the upper slopes where bottom waters are sufficiently aerated to support a normal benthic fauna, burrowing organisms and deposit feeders should be expected to keep the sediments well stirred up so that a homogeneous deposit would result. In the deeper parts of the basin where conditions are anoxic, at least at present, no benthic organisms would be expected and laminated sediments should occur in response to changes in the rates of sedimentation between the wet and dry seasons as suggested by Hülsemann and Emery (1961). Both types, homogeneous silty clays and finely laminated silts, are found at the tops of the cores from the area, but the former are not restricted to the shallower areas nor are the latter restricted to the deeper areas. About the only generalization that can be made in this respect is that laminated sediments are more prevalent in the tops of the cores from the eastern part of the trench while homogeneous sediments are slightly more prevalent in the western part, but this distribution bears no relationship to depth. A possible factor in this distribution is the probable higher sedimentation rate in the eastern basin due to higher biological productivity in the upper waters and to a relatively closer proximity to the sources of terrigenous

sediments since the general current drift in the region is from east to west. However, as the piston corer frequently disturbs the top layers, perhaps sometimes does not sample them at all, and as the core catcher in the pilot corer is likely also to disturb the softer top layers, some of the inconsistency of the surface sediment structure pattern is very likely artificial and it may be pointless to pursue the question further.

Bottom photographs B through F (Plate I) show bottom surface conditions which are probably typical for various environments within the trench. Photo B, from 245 meters on the north slope of the western basin at Core Station 7, shows a soft looking, fine-grained, deserted bottom strongly contrasting with the well populated bottom of Photo A. The numerous pits visible in the photograph however, indicate that burrowing organisms are present and active even though dissolved oxygen content of the water immediately above is estimated at only 1 milliliter per liter. Consequently the sediments here should be expected to be homogeneous, and indeed this is what is found at the top of Core 7. Photo C, from about the same depth (269 m.) at Core Station 23, southwest of Margarita Island, is somewhat puzzling, probably in part due to the fact that it is slightly out of focus. No organisms or evidences of their activities can definitely be discerned and yet it would be difficult to explain such peculiar bottom irregularities in terms of nonorganic factors. The depth here borders on the euxinic zone and there is probably less than 1 ml/l. of dissolved oxygen in the bottom water. This, considered together with the strong odor of H_2S noted in the core sediment immediately after collection and the fluffy nature of the extruded sediments in the upper two or three meters of the core, suggests that the irregularities might be aggregations of partially decomposed organic materials from the highly productive (Curl, 1960) waters above. The softness of such a sediment would also explain why the photograph was slightly out of focus since the tripping

weight for the camera shutter would have penetrated the bottom somewhat before releasing the tension on the shutter spring allowing the camera to approach the bottom nearer than usual.

Photo D, shows a soft, fine-grained sediment at the location of Core Station 8. Here there appear to be small pits as if burrowing organisms were present, but as the depth is 512 meters, well into what is considered to be the euxinic zone, this would be very doubtful except that this location is also in the vicinity of the deeper connecting channel at the west end of the trench, and oxygenated water from outside the sill may periodically reach it. The striated appearance of the bottom in the photograph (from lower left to upper right) suggests ripples which might be formed by currents associated with a periodic flushing. Photos E, and F, are from the deep parts of the western and eastern basins respectively (1160 and 1340 m.). These show fairly uniform fine-grained, deserted bottoms, although in Photo E, from near Core Station 12, there are some small pits suggestive of burrows. On the basis of present hydrographic information however, it seems highly improbable that burrowing organisms could live there.

As the surface sediments are similar in general detail to those deeper in the cores, description of their coarse fractions will be deferred to the section on subsurface sediments. Clay analyses (Table III) were made of the fraction finer than 4.0 microns of the upper 10 to 15 centimeters of twelve cores, but were not repeated deeper in the cores. A brief outline of the results follows. The principal clay minerals are illite, ranging from 40 to 50 percent of the fine fraction from each sample, and chlorite, ranging from 30 to 40 percent. Montmorillonite occurs in each sample but its content is somewhat lower (10-20%). Although there is a range of ten percent in the chlorite content, the arithmetic mean of the percentages is 38, showing that the chlorite content is generally quite constant throughout the trench. In respect to the other two clay minerals, slightly higher contents of illite

are found in the samples of the western basin while, conversely, lower percentages of montmorillonite are found at the westerly end of the western basin (10 to 15%), but elsewhere it has a fairly constant 20 percent content.

Subsurface Sediments of the Trench

The three profiles, A-A', B-B', and C-C' (Figures 4, 5, and 6) are considered to give a reasonable indication of Holocene deposition in the Cariaco Trench and, probably at upper slope locations, of some late Pleistocene deposition as well. Vertical exaggeration is approximately seven to one on these profiles. Depths are given in fathoms at the left margin of each figure and meters at the right margin. The tops of the core diagrams are located at their geographical and topographical positions on the profiles and extend below the profile in proportion to their lengths, shown by the centimeter scales beside each core representation.

Because of the condensation necessary, the characteristics of each core are shown only in a very general way, but highly detailed sketches to a scale of one inch (2.5 centimeters) per ten centimeters of core length were prepared originally and are available for any future specific studies. The predominant color of the sediment and general zonation in regard to sediment texture and structure are indicated (see legend accompanying profiles). As also explained in the legend, the relative abundance of fossil remains, particularly foraminifera and pteropods, is shown by the numbers usually placed within the core diagrams. Occasionally the number is shown to one side if the stratum represented is too thin to accommodate it within the sketch. In addition to the one inch to ten centimeter sketches of the individual cores, detailed descriptions and commentaries were prepared for each and these form the basis for the following general discussion of the subsurface sediments of the trench.

Two major sediment zones encountered are most clearly defined by color differences. In general, the upper sediments, ranging from 20 to over 900 centimeters in thickness are grayish-olive to greenish-gray in color. Sediments of the lower zone, where encountered on the south side of the trench, are olive-gray to yellowish-brown, while those on the north side of the western basin (Profiles A-A' and B-B') are dusky-yellow-green. Except for a short section of olive-gray sediment noted but not sampled at the bottom of Core 22, none of the lower zone sediments were encountered at the north side of the eastern basin. The boundary between the upper zone and the lower zone on the south side of the trench, which is usually fairly sharp is considered to represent the end of the Pleistocene as a radiocarbon date of 10,900 years was obtained from just above this position in similar cores collected from the same area by the Lamont Geological Observatory (Heezen et al., 1958).

The more greenish, Holocene sediments occupy the top 200 to 300 centimeters in the cores from the upper and middle slopes of the trench. In the basin bottoms and on the sloping platform southwest of Margarita (Profile C-C') they extend clear to the bottoms of the cores. They are either very finely laminated or homogeneous silts and clays. These two types usually alternate within a core, although in the cores with longer Holocene sections the homogeneous sediments predominate deeper in the core while the laminated zones are concentrated toward the top. As discussed perviously there seems to be no particular geographical relationship between cores with laminated sediments at the surface and those with homogeneous sediments at the surface except that the top zones of the cores at the deepest points on each profile are homogeneous, and more cores on the eastern profile have laminated top zones than on the other profiles. Thickness of the zones varies greatly, ranging from a few millimeters to over 300 centimeters for both types of sediment, and such variation occurs even between adjacent cores, for example between Cores 21 and 18 on Profile C-C'.

The coarse fractions of the laminated sediments range from 2 to 6 percent of the total sample weights; those of the homogeneous sediments are a little lower, 1 to 3 percent. Pelagic foraminifera, pteropods, larval bivalves and tiny fish scales and bones constitute the bulk of the coarse fractions. Thus the laminated sediments give the appearance of being moderately to highly fossiliferous while the homogeneous sediments have a comparatively lower faunal content. Qualitatively however, the faunal types are generally similar in adjacent zones regardless of whether the sediment is laminated or homogeneous. The foraminifera consist of Orbulina, several species of Globigerina, Globigerinoides and of minute species of Bolivina which were suspected of being pelagic and have indeed been found in plankton tows from near the entrance of the Gulf of Cariaco (G. Seiglie, personal communication). Species of Globorotalia are common only in the sediments of the sloping platform southwest of Margarita. In the deeper cores away from littoral influences there is little in the nature of a benthic fauna, as would be expected in an anoxic basin, whereas at Core Station 7, at the northern end of Profile A-A', and at 19 at the southern end of Profile C-C', there are many benthic species of foraminifera (Miliolidae, Buliminidae, Nonionidae, Lagenidae, Rotaliidae and others) along with mollusks, ostracods and echinoid spines. The presence of a benthic fauna throughout Core 14 (Profile B-B') from the north slope of the western basin just at the top of the anoxic zone may indicate that there is enough oxygen here to support a bottom community, but the presence also of abundant calcareous and other detritus suggests that more likely there has been continuous displacement of sediments from higher elevations on the shoal area seaward of the trench. In these peripheral cores small amounts of quartz sand are also found. In Core 18, at the very bottom of the center of the eastern basin, a similar benthic and terrigenous element is oddly enough

present in the samples studied, suggesting possibly a continual influx of sediment either from the shallow channel between Margarita and the Araya Peninsula or from the Gulf of Cariaco. Core 16, from the saddle area between the deep basins, is composed mostly of laminated sediments which contain also a sparse benthic fauna among a fairly rich pelagic fauna.

The upper 73 centimeters of Core 24, at 333 meters (Profile C-C'), are composed of a laminated, highly organic sediment with a rich pelagic fauna typical of the anoxic zone elsewhere. Between 73 and 77 centimeters, however, there is a "sandy" zone composed almost entirely of pelagic and benthic fossils and a high percentage of fecal pellets, presumably from benthic organisms. Below this zone the sediment is moderately fossiliferous to the bottom of the core and contains both a pelagic element (predominant) and a benthic element. The entire column of sediment appears to be Holocene and it would seem that at this higher level in the trench conditions have become euxinic only much more recently than at deeper levels.

In a few other cores, narrow, sandy bands (1-5mm. thick), which are actually Globigerina or pteropod "oozes", are found. Three occur in the upper 110 centimeters of Core 9, one in Core 10, 16 in Core 16, one in Core 18 and one in Core 22. They consist mostly of globigerinids, in some zones almost purely so, and elsewhere with also a considerable percentage of pteropods. Their occurrence is so sporadic, however, that there seems to be no way of correlating them and they appear to result from purely local phenomena, perhaps from mass killing by occasional "bubbles" of anoxic water reaching the upper layers due to sudden density changes, or conversely, of "bubbles" of surface water sinking to the anoxic zone due to sudden and abnormal cooling.

In none of the Holocene sediments so far discussed have there been any evidences of turbidites, even though there have been some peculiar

changes in the nature of the faunal contents of adjacent zones. The one exception found within the Cariaco Trench sediments was Core 9 from the western end of the deep part of the western basin (Profile A-A'). The upper 120 centimeters of sediment appears to be normal, but between 120 and 157 centimeters there are five units containing graded beds of fairly fine material (fine sands at the bottom to silty clays above). Between 161 and 182 centimeters there is a heterogeneous gravelly layer consisting of quartz granules, rock fragments, littoral mollusks and chunks of silty clay. A moderately fossiliferous, normal, homogeneous silt-clay underlies this layer down to 215 centimeters. From this level to the bottom of the core, over 150 centimeters, the sediment is again a heterogeneous mixture like that described above, but with a higher percentage of clayey matrix. It appears that here at the steep end of the trench, near mountainous Cape Codera, there occur occasional slumpings of terrigenous sediments originally deposited at or near the rim of the trench. Apparently turbidity currents are sometimes precipitated during these movements, but they seem to travel only short distances before they are dispersed because no other evidences of turbidities have been found. The fact that little or no overburden was found above the lower major sediment zone (to be discussed next) in two of the cores from the south slope (Cores 11 and 20) suggests that these slumps may occur all along the southern margin of the trench, but unless a core, such as core 9, were fortuitously taken at the very bottom of the steep slope the displaced overburden would not be found.

The yellowish-brown sediments of the lower zones of Cores 11, 21 and probably from the entire section represented by Core 20, which was not studied in detail, are from below the 10,900 year level of Heezen et al. (1958) and are therefore most likely late Pleistocene in age. These are homogeneous clays with a very sparse coarse fraction (less than one percent). In composition, the coarse fraction consists of about 50 percent

pelagic foraminifera and pteropods, mostly Quaternary and about 40 percent Quaternary benthic foraminifera including Miliolidae, Nonionidae, Lagenidae, Bolivinidae (some of which may be pelagic as noted earlier), Rotaliidae and Anomalinidae, and ostracods. The remaining 10 percent is made up of reworked Tertiary foraminifera and terrigenous minerals. It appears both from the faunal record and from the brownish color that during the period of deposition of these sediments well aerated, marine conditions prevailed in the water column and that there was a small contribution from land run-off at the south side of the trench.

There is a five to twenty centimeter transitionary subzone, more olive in color, between the upper grayish-olive zone and this lower yellowish-brown zone. The coarse fraction has the same characteristics as those just described for the lower zone except that glauconite and pyrite occur in abundance. The former occurs as test fillings and as globular grains, and the latter occurs also as test fillings and as tiny spherical or discoidal crystal aggregates or as short, twisted filaments two to five millimeters long and one-tenth to three-tenths of a millimeter thick. The occurrence of glauconite which is considered to be formed under reducing conditions and usually associated with iron sulfide (Takahashi, 1939, p. 503; Lochman, 1949, p.57), in this case pyrite, in association with a bottom fauna indicative of well aerated bottom conditions, suggests that as bottom conditions became euxinic following the end of the Pleistocene, there was sufficient diffusion within the topmost ten or twenty centimeters of the lower sediment zone to produce reducing conditions with the resulting formation of glauconite and pyrite. Although the present depth of 960 meters for Core 21 is considered deep for the authigenic production of glauconite (Cloud, 1955), at the time of formation the water depth was probably at least one hundred meters shallower. Further, depth may not really be the controlling factor in the formation of glauconite but

rather, it may be that the reducing conditions required for its formation occur much more frequently in shallower than in deeper parts of the sea, and thus glauconite formation is more generally associated with lesser depths.

Core 19 (Profile C-C'), composed principally of homogeneous silty clay, grayish-olive above 300 centimeters, and olive-gray below, contains an abundance of glauconite and pyrite throughout its length along with a moderate benthic fauna. Richards' (1960) profile II, p. 173, indicates that dissolved oxygen is minimal in the bottom waters at the depth of this core (170 meters). The fact that the glauconite and pyrite occur throughout the core, but with benthic organisms, suggests that although there is enough oxygen to support benthic life on the bottom, reducing conditions have probably prevailed just below the water-sediment interface during the entire period of deposition represented by the core. Thus it appears that these latter olive-gray glauconite and pyrite bearing sediments of the lower zone of Core 19 are post-Pleistocene, and are not to be correlated with the lower zones of Cores 11 and 21. The change in color in Core 19 from grayish-olive above to olive-gray below may indicate a decrease in water content with depth below the bottom rather than a change in the environment of deposition.

The dusky-yellow-green silty clays from the lower part of Cores 7 and 14 from the upper slopes at the north side of the western basin are similar in coarse fraction content to the grayish-olive sediments in the zone above. The difference in color here may also simply relate to a difference in degree of compaction and water content. As no radiocarbon date has been obtained for this zone and since it is probable that at least part of the sediment is displaced from the shoal area to the north, just as it appears to be in the upper zone, it would seem that these dusky-yellow-green clays should not, at least on the basis of present data, be correlated with the yellowish-brown clays of the lower zone at the south

side of the Cariaco Trench.

CONCLUSIONS

As had been anticipated by the previous observations of the hydrography of the Cariaco Trench, the sediments of the deeper basins do, by and large, reflect the anoxic character of the waters below approximately 375 meters. Most of the faunal remains in these sediments are either pelagic or their presence can be attributed to transport from shallower, aerated environments. It is not clear why there should be alternations between homogeneous sediments and laminated sediments in the deep areas. Qualitatively the faunal content is about the same in either type, although there is a slightly lower percentage of coarse fraction in the homogeneous beds. The laminated sediments may be attributed to changes in the rate and quality of sedimentation due to the alternation of wet and dry seasons. In the absence of a benthic burrowing fauna the individual laminae, or varves, should remain undisturbed. The homogeneous sediment, on the other hand, might in shallower areas represent a sediment thoroughly mixed by benthic organisms, but within the deeper basins of the trench this could not be so unless the trench were occasionally flushed by outside aerated sea-water. The comparative thickness of the homogeneous beds, the lack of fossil evidence for a radical increase in benthic fauna, and the non-correspondence between layers in nearby cores argues against this view however. Further complicating the sedimentation picture in the trench is the sporadic occurrence of layers of *Globigerina* ooze in a few of the cores, but not in others. All of these things seem to point to very local sedimentary influences rather than to regional climatic changes. Turbidity currents initiated by slumping might provide part of the answer

except that graded bedding, normally associated with them is recognized in only one core at the very western end of the trench.

It is possible to locate the transition between the late Pleistocene and the Holocene in cores from the south slope. In the deeper basins and on the northeastern slopes of the trench, sediment accumulation has been sufficiently great that the cores did not penetrate to the Pleistocene boundary. It seems probable also that the cores from the northern slope to the west of Tortuga are Holocene.

The highly organic appearance of the sediments from the platform area to the southwest of Margarita suggest that primary production in the waters above the trench is highest in this area although Curl's (1960) measurements showed production at the time of measurement to be highest over the south central portion of the trench. It is unfortunate that samples were not adequately preserved for reliable organic carbon analyses since the bottom sediments should give a synoptic picture of production in the overlying waters while water measurements can only apply to the season in which the measurements were taken.

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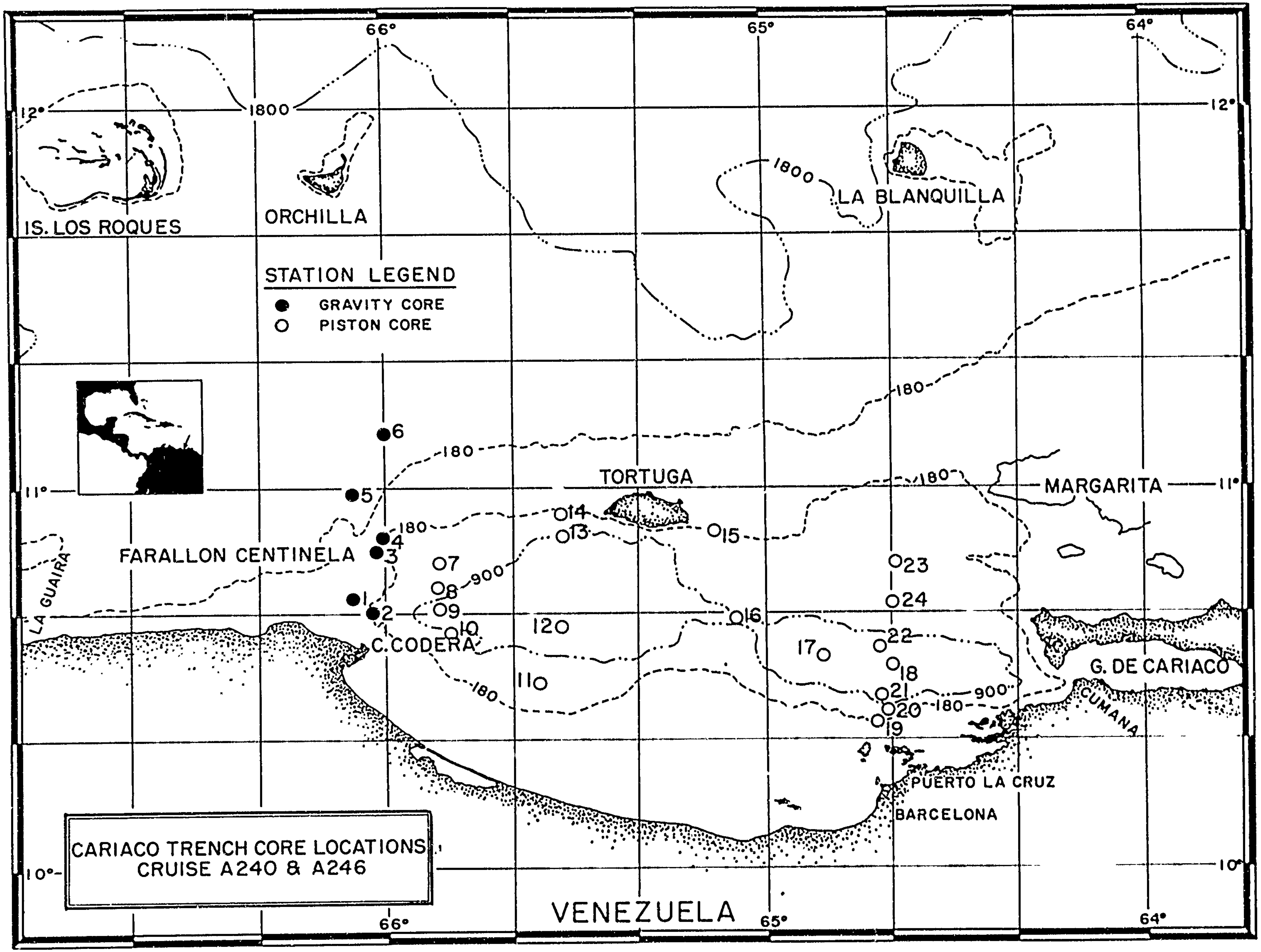

FIGURE 1. Cariaco Trench Core Locations

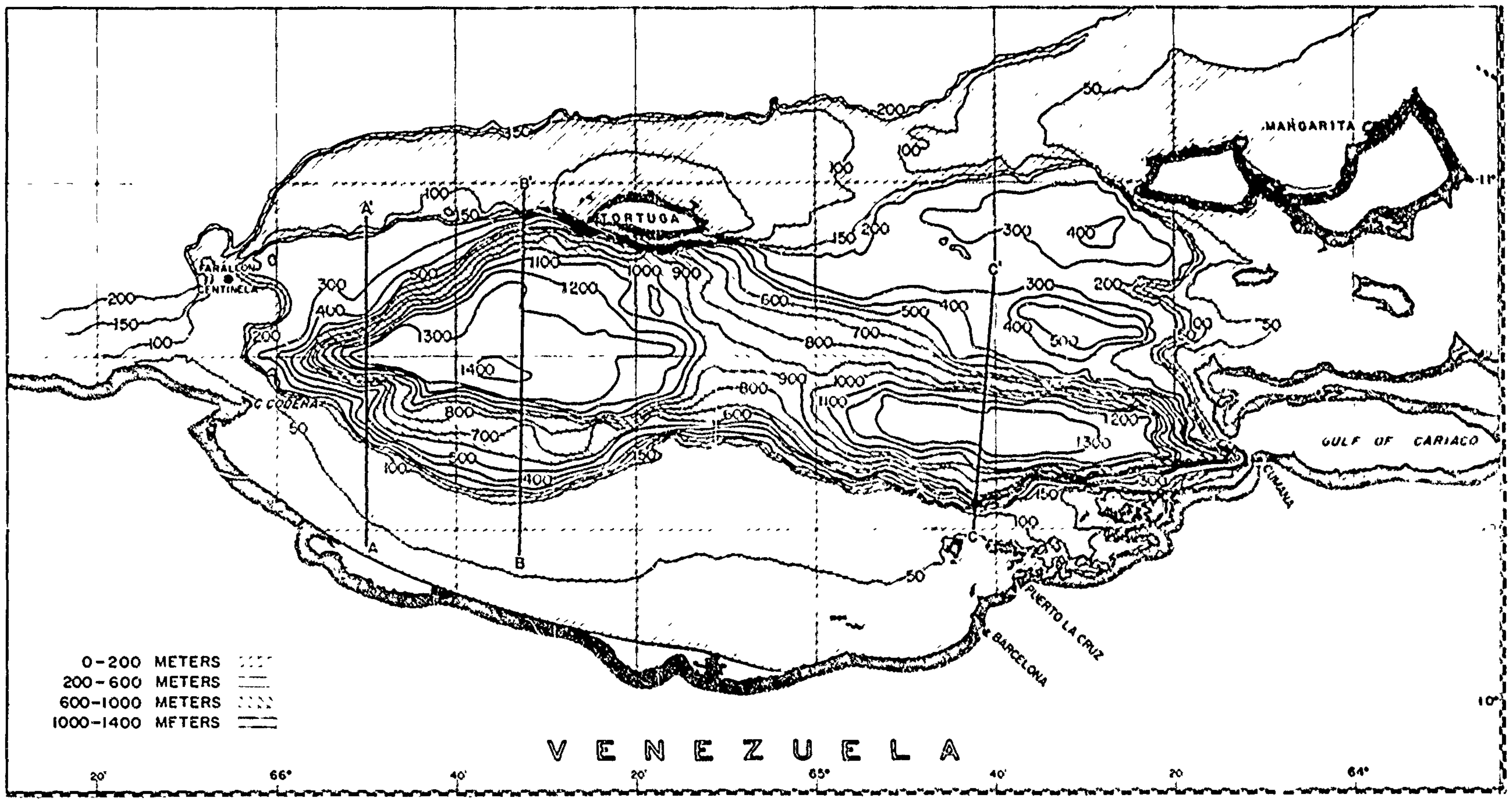

Figure 2. Bathymetric Map of the Cariaco Trench

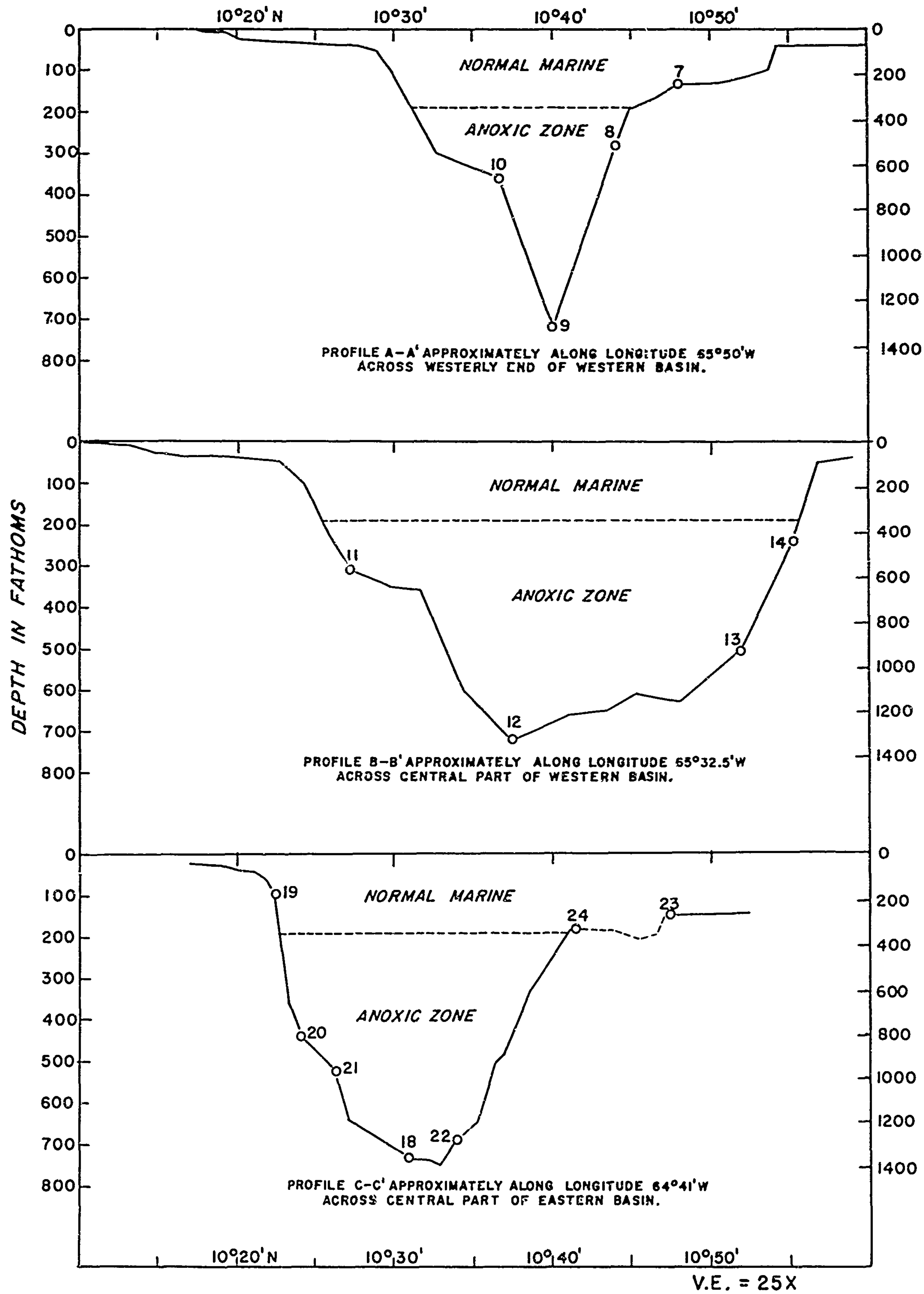

Figure 3. Coring Profiles across the Cariaco Trench

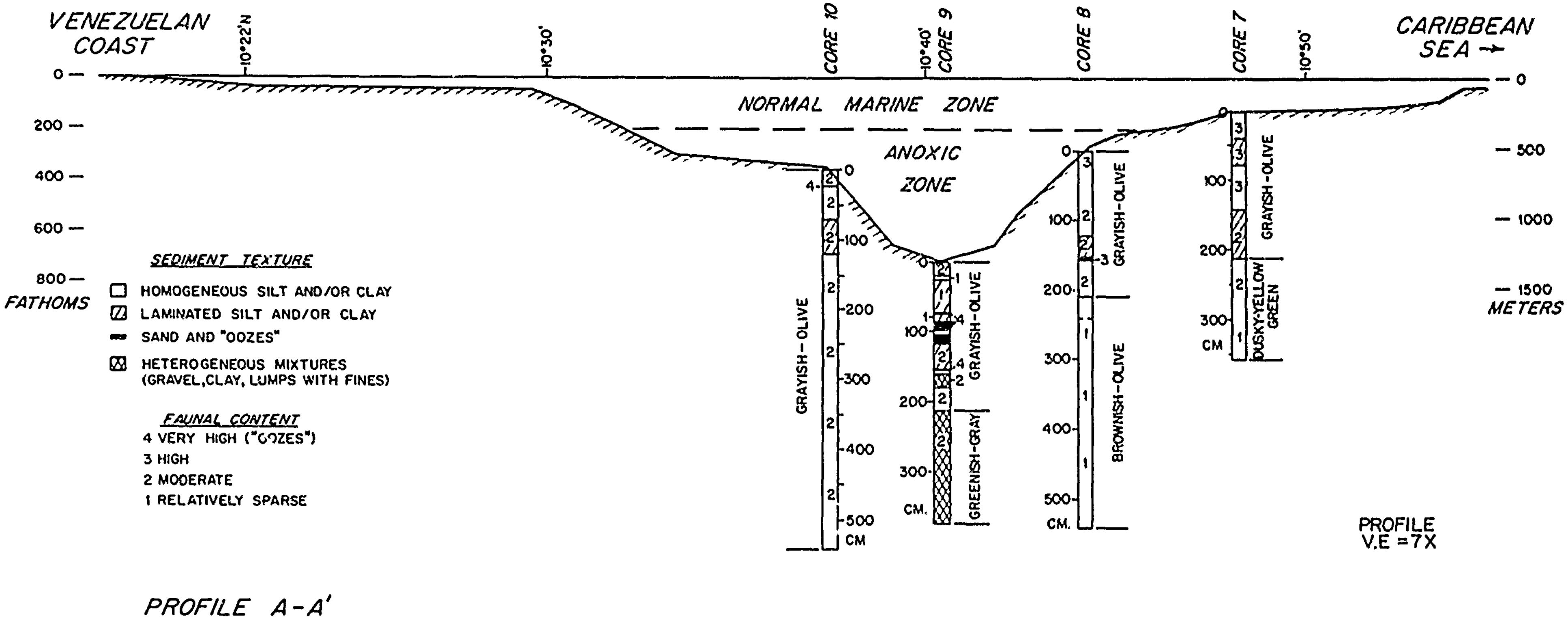

Figure 4. Profile A-A' across the westerly end of the western basin of the Cariaco Trench, approximately along Longitude 65°50'W.

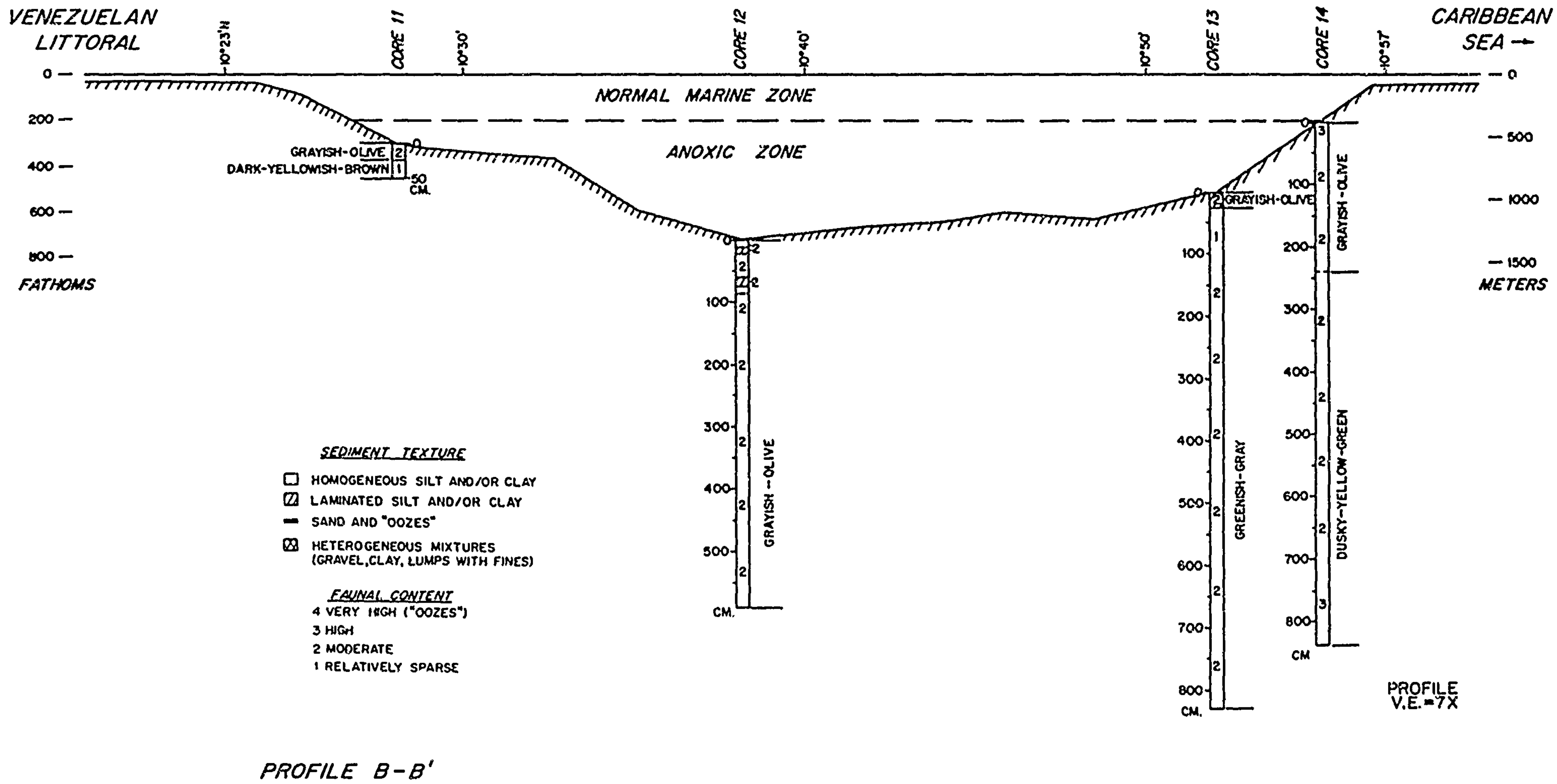

Figure 5. Profile B-B' across the center of the western basin of the Cariaco Trench, approximately along Longitude 65°32.5'W.

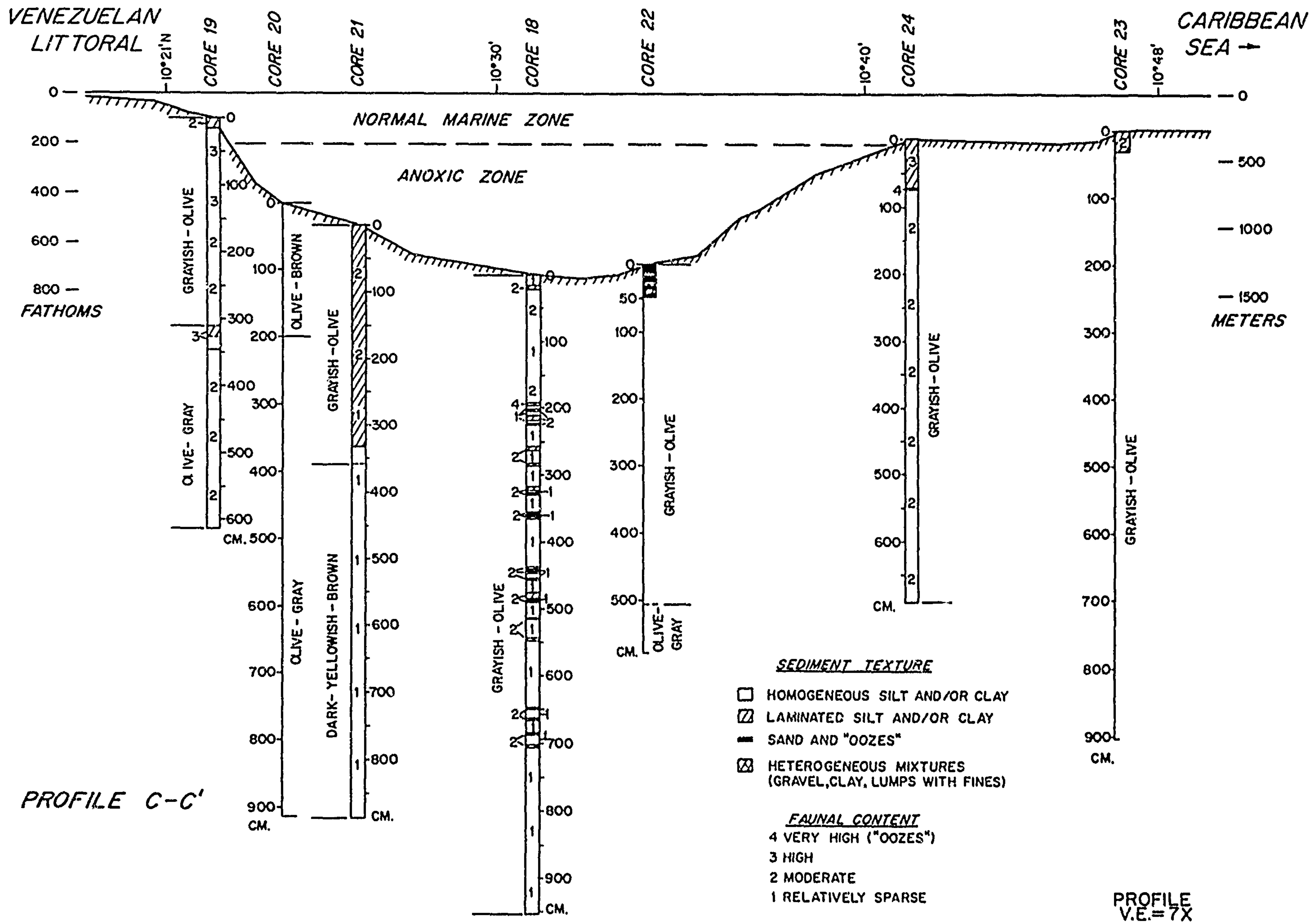

Figure 6. Profile C-C' across the center of the eastern basin of the Cariaco Trench, approximately along Longitude 64°41'W.

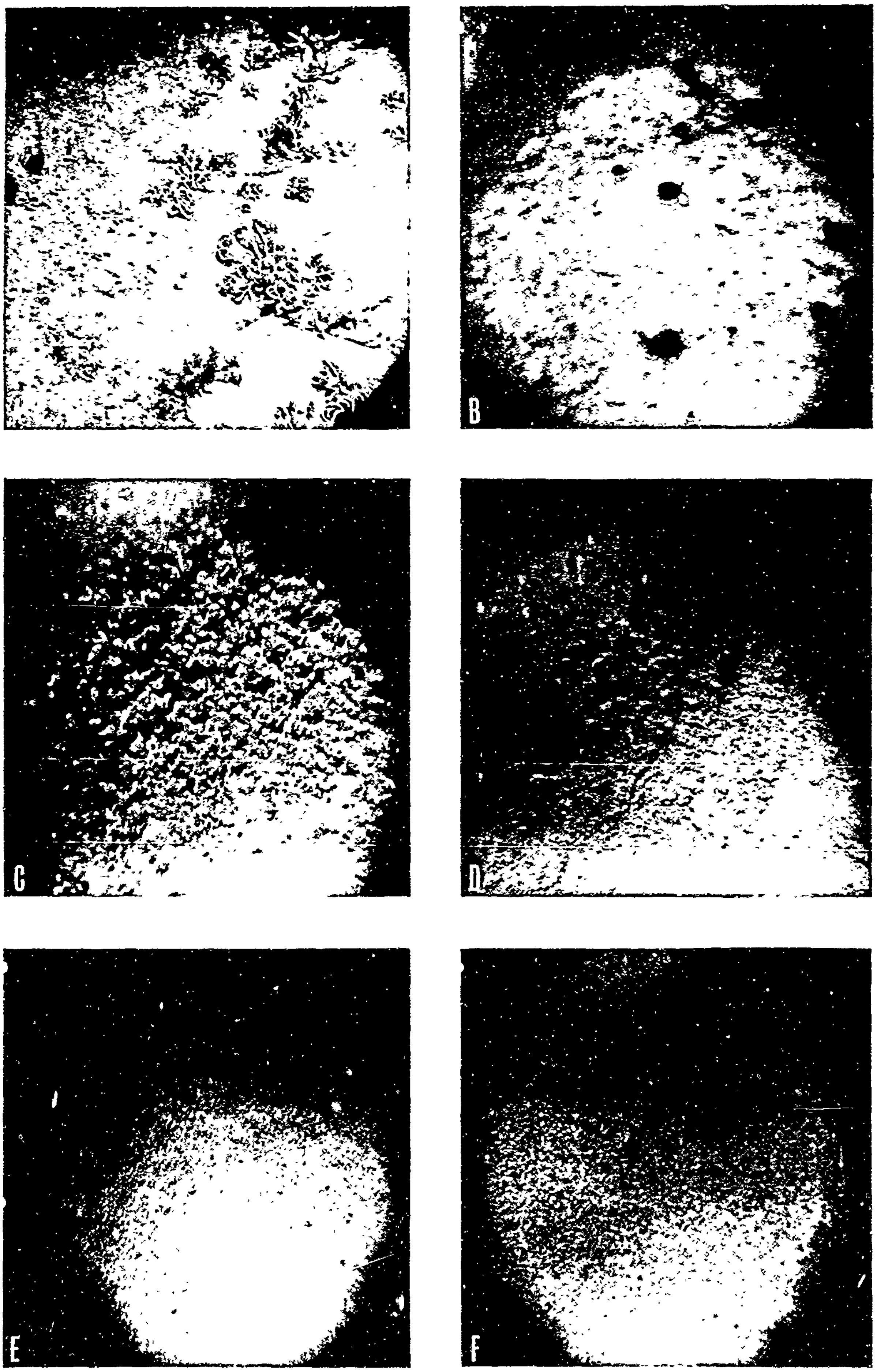

Plate 1. Bottom Photographs from the Cariaco Trench.

TABLE I Core Statistics

Core No.	Date	Lat. (N)	Long. (W)	Depth (m)	Core * Type	Length (cm)	General Comments
1	1-XI-57	10°42.0'	66°05.0'	71	G	66	Heterogeneous, coarse throughout.
2	"	10°40.0'	66°02.2'	269	G	130	Fine shells and olive-gray mud.
3	"	10°49.0'	66°01.2'	176	G	2	Lithified detritus in marl.
4	"	10°51.5'	66°00.4'	180	G	10	Silty sand with marine fossils and terrigenous.
5	"	10°58.8'	66°05.0'	265	G	94	Gray sandy silt.
6	2-XI-57	11°08.2'	66°00.0'	357	G	18	Medium sand.
7	"	10°48.0'	65°51.5'	245	P	359	Silt, gray-olive to 210; yellow-green silty clay below.
8	"	10°44.0'	65°51.7'	512	P	542	Silt, gray-olive to 150; olive-gray to brown-olive below.
9	3-XI-57	10°40.7'	65°51.5'	1317	P	375	Very heterogeneous suggests intermittent slumping.
10	"	10°36.7'	65°49.8'	658	P	543	Silty clay, grayish-olive
11	4-XI-57	10°28.8'	65°35.7'	558	P	56	Silty, gray-olive to 20; clay, yellow-brown below.
12	"	10°37.5'	65°32.4'	1320	P	591	Grayish-olive silts and silt-clays.
13	5-XI-57	10°51.8'	65°31.8'	923	P	830	Silty, gray-olive to 25; clayey, greenish-gray below.
14	"	10°55.2'	65°32.2'	373	P	840	Clay, gray-olive to yellow-green.
15	6-XI-57	10°52.5'	65°08.0'	348	P	580	Core badly disturbed.
16	7-XI-57	10°38.7'	65°04.5'	896	P	715	Gray-olive silts and clays, with bands of Globigerina ooze.
17	"	10°32.6'	64°51.2'	1323	P	760	Dark-gray-olive, silty.
18	"	10°30.8'	64°40.0'	1344	P	952	Gray-olive silts and clays.
19	8-XI-57	10°22.3'	64°42.5'	170	P	612	Silty, gray-olive to 345; olive-gray, clayey below.

* G: Gravity Corer P: Piston Corer

Table I continued

Core No.	Date	Lat. (N)	Long. (W)	Depth (m)	Core Type	Length (cm)	General Comments
20	8-XI-57	10°24.0'	64°41.2'	805	P	915	Clayey, olive-brown to olive-gray.
21	9-XI-57	10°26.2'	64°41.5'	960	P	686	Clayey, gray-olive to350; yellow-brown below.
22	"	10°34.0'	64°41.8'	1257	P	580	Silty, gray-olive to 500; clayey, olive-gray below.
23	"	10°47.2'	64°39.6'	269	P	905	Silt-clay, dark-gray-olive; highly organic throughout.
24	2-XI-58	10°41.3'	64°40.0'	333	P	653	Clayey, dark-gray-olive; highly organic throughout.

TABLE II

ELEMENTAL ANALYSES OF CARIACO TRENCH SAMPLES*

Woods Hole Core Number	JPRC Sample Number	Organic Carbon	Organic Plus Ammoniacal Nitrogen	Total Sulfur	Total Phosphorus	Depth m.
8	23100	2.24	0.36	1.93	0.09	510
9	23101	2.01	0.35	1.73	0.09	1315
10	23102	1.97	0.33	2.32	0.07	660
11	23103	1.81	0.28	2.33	0.11	560
12	23104	1.61	0.39	2.34	0.12	1320
13	23105	2.36	0.35	2.50	0.13	925
14	23106	2.66	0.34	1.77	0.13	375
19	23107	1.16	0.23	1.11	0.16	170
20	23108	0.69	0.23	2.27	0.11	805
21	23109	2.44	0.38	2.33	0.07	960
22	23110	2.37	0.36	1.96	0.07	1260
23	23111	1.30	0.21	2.00	0.09	270

* All values are in weight per cent of dry sediment.

TABLE III

CLAY MINERAL ANALYSES OF CARIACO TRENCH SAMPLES

Woods Hole Core Number	JPRC Sample Number	Illite %	Chlorite %	Montmorillonite %
8	23100	50	40	10
9	23101	50	40	10
10	23102	50	35	15
11	23103	45	40	15
12	23104	50	30	20
13	23105	40	40	20
14	23106	45	35	20
19	23107	45	35	20
20	23108	40	40	20
21	23109	40	40	20
22	23110	40	40	20
23	23111	40	40	20